

On the Origin of Metals in Some Hot White Dwarf Photospheres

Matt R. Burleigh*, Martin A. Barstow*, Jay Farihi*, Nigel P. Bannister*,
 Nathan Dickinson*, Paul R. Steele*, Paul D. Dobbie†, Francesca Faedi**
 and Boris T. Gaensicke‡

**Dept Physics and Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK*

†*Australian Astronomical Observatory, PO Box 296, Epping, NSW 1710, Australia*

***Astrophysics Research Centre, School of Mathematics and Physics, Queen's University,
 University Road, Belfast, BT7 1NN, UK*

‡*Department of Physics, University of Warwick, Coventry, CV4 7AL, UK*

Abstract. We have searched for evidence for dust and gas disks at a sample of hot DA white dwarfs $20000K < T_{\text{eff}} < 50000K$, without success. Although their atmospheres are polluted with heavy elements, we cannot yet convincingly and conclusively show that any of these objects is accreting metals from surrounding material derived from disrupted minor planets in an old solar system.

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INTRODUCTION

The discovery of a growing number of dust disks around cool ($< 22000K$) DAZ white dwarfs (WD) has been linked to the existence of old planetary systems containing terrestrial bodies. The dust disks are thought to originate from the tidal disruption of a minor planet that has wandered too close to the WD (6). At temperatures $> 20 - 25000K$, any dust close to the WD will be sublimated and produce no infrared emission, although in a few WDs $\sim 20000K$ a gas disk exists in addition to warm dust. The gas disks are revealed by Ca II emission at $\approx 8600\text{\AA}$ and sometimes Fe II emission at $\approx 5200\text{\AA}$ (5).

Heavy elements are ubiquitous in the atmospheres of DA white dwarfs at $T_{\text{eff}} > 50000K$ (2, 7), and are present in some, but not all, objects at temperatures cooler than this. Above $50000K$, metals are levitated in the stellar photospheres against the strong gravitational field by radiation pressure. For single stars, it is impossible to distinguish whether their origin is primordial or due to accretion. But below $\approx 50000K$, the metal abundances sometimes cannot be explained by diffusion theory alone. Indeed, exactly which elements may be present, and in what abundances, can vary between stars of seemingly identical temperatures and masses (3). As with the cooler DAZ white dwarfs, the gravitational settling times for these heavy elements are so fast that some hot white dwarfs $< 50000K$ may be undergoing low level accretion from an unknown external source. The discovery of dust and gas disks around some DAZs suggests these may also be the source of the material seen in the photospheres of some hotter white dwarfs between $20000K$ and $50000K$.

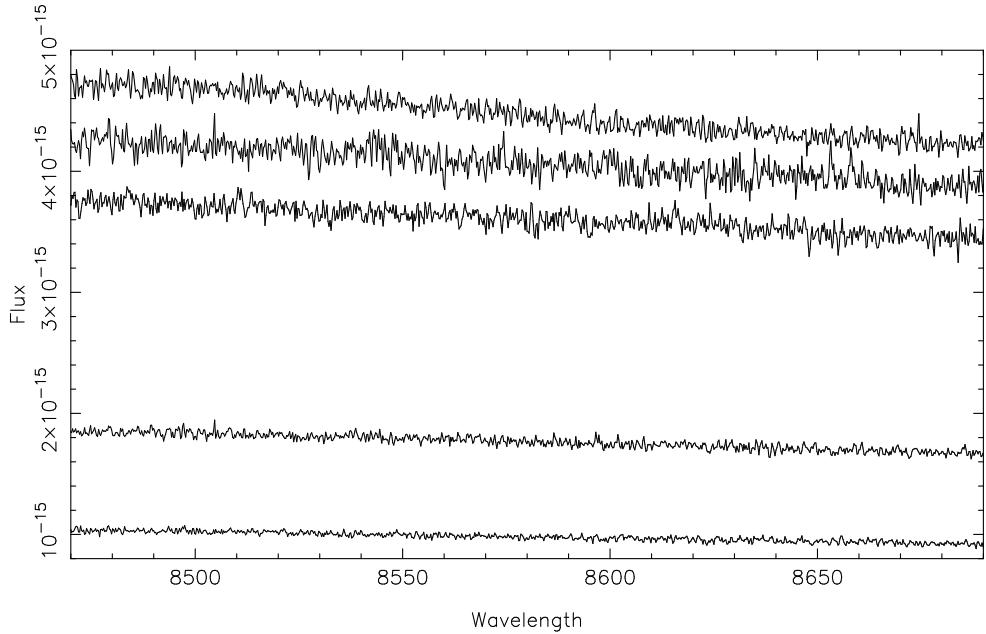


FIGURE 1. Red optical spectra of hot DA white dwarfs centred on the Ca II 8498Å, 8542Å, 8662Å triplet. Top to bottom: HS0209 + 083, GD394, REJ1943 + 50, GD246, REJ1614 – 085.

SPITZER MID-INFRARED OBSERVATIONS OF HOT WHITE DWARFS

We used Spitzer/IRAC to search for excess mid-IR emission, potentially due to the presence of warm dust, in a sample of hot DA WDs $20\,000\text{K} < T_{\text{eff}} < 50\,000\text{K}$, whose photospheric heavy element composition we had previously studied in detail in the far-UV and EUV (3, 1). Data were obtained in our own programmes, and from the Spitzer public archive. Only one star, PG1234 + 482, shows any excess emission, due to the presence of an L0 dwarf companion (8, 9). The non-detection of warm dust at these hot degenerates is not entirely unexpected, given our current expectation that the known disks lie within a few solar radii of their WD hosts, and that at higher WD temperatures this material will likely be sublimated.

AN OPTICAL SEARCH FOR CA AND FE EMISSION IN HOT WHITE DWARF SPECTRA

We obtained optical spectra of ten hot DA white dwarfs studied by Barstow et al. [3] to search for emission lines of the Ca II triplet near 8600Å and Fe II near 5200Å, indicative of the presence of a gas disk. We used the 4.2m William Herschel Telescope and the ISIS spectrograph with the $R = 1200$ gratings. No such emission lines were observed in any object (Figure 1), although Si III absorption was detected in GD394 (also by 4) and Fe II absorption in HS0209 + 083.

DISCUSSION - IS THERE ANY EVIDENCE THAT HOT WDS ARE ACCRETING THEIR METALS FROM DISRUPTED MINOR PLANETS?

The non-detection of warm dust or gaseous emission from the Barstow et al. [3] sample of metal-rich hot WDs is disappointing but not necessarily a surprise. At a stretch, radiative levitation may still explain their abundances, although the considerable variations between objects with similar temperatures and surface gravities suggests accretion from unseen companions or circumstellar debris (see also 10). The presence of disks around cooler WDs, and the conclusion that they are accreting the remains of disrupted terrestrial bodies, suggests the same phenomenon must be occurring at higher temperatures. Indeed, one well-studied object, GD394 ($T_{\text{eff}} \approx 38000\text{K}$), displays a silicon abundance ≈ 100 times higher than any other degenerate at similar temperature and gravity. In addition, the silicon is inhomogeneously distributed across the WD surface ($P_{\text{rot}} \approx 1.15$ days, 4). There is a strong temptation to conclude that GD394 is accreting from surrounding silicate-rich material, just as with the cooler DAZs, despite the lack of evidence for the presence of a dust or gas disk in the observations discussed above.

In fact, there is evidence for circumstellar material at these hot WDs in existing far-UV observations. Bannister et al. [1] noted the presence of velocity shifted lines of e.g. C IV, Si IV, and N V in addition to photospheric and interstellar components, and discussed possible origins for these features including ionization of the local interstellar environment, the presence of material inside the gravitational well of the white dwarf, mass loss in a stellar wind and the existence of material in an ancient planetary nebula around the star. With hindsight, the link to dust and gas disks at cooler DAZs becomes more enticing. But the question remains - can we convincingly and conclusively prove that individual hot WDs are accreting from surrounding material derived from disrupted minor planets in an old solar system?

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